Chapter 4. Sediment Characteristics

INTRODUCTION

Sediment conditions can influence the distribution of benthic invertebrates by affecting the ability of various species to burrow, build tubes or feed (Gray 1981, Snelgrove and Butman 1994). In addition, many demersal fishes are associated with specific sediment types that reflect the habitats of their preferred prey (Cross and Allen 1993). Both natural and anthropogenic factors affect the distribution, stability and composition of sediments.

Natural factors that affect the distribution and stability of sediments on the continental shelf include bottom currents, wave exposure, proximity to river mouths, sandy beaches, submarine basins, canyons and hills, and the presence and abundance of calcareous organisms (Emery 1960). The analysis of various sediment parameters (e.g., particle size, sorting coefficient, percentages of sand, silt and clay) can provide useful information relevant to the amount of wave action, current velocity and sediment stability in an area.

The chemical composition of sediments can also be affected by the geological history of an area. For example, sediment erosion from cliffs and shores, and the flushing of sediment particles and terrestrial debris from bays, rivers and streams, contribute to the composition of metals and organic content within an area. Additionally, nearshore primary productivity by marine plankton contributes to organic input in marine sediments (Mann 1982, Parsons et al. 1990). Finally, concentrations of various constituents within sediments are often affected by sediment particle size. For example, the levels of organic materials and trace metals within ocean sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Vanketesan 1993).

Ocean outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of ocean sediments through the discharge of wastewater and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds discharged via outfalls are trace metals, pesticides and various organic compounds (e.g., organic carbon, nitrogen, sulfides) (Anderson et al. 1993). Moreover, the presence of large outfall pipes and structures associated can alter the hydrodynamic regime in the immediate area.

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2006 in the vicinity of the South Bay Ocean Outfall (SBOO). The primary goals are to: (1) assess possible impact of wastewater discharge on the benthic environment by analyzing spatial and temporal variability of various sediment parameters, and (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site.

MATERIALS AND METHODS

Sediment samples were collected during January and July 2006 at 27 stations surrounding the SBOO (**Figure 4.1**). These stations range in depth from 18 to 60 m and are distributed along 4 main depth contours. Listed from north to south along each contour, these stations include: I35, I34, I31, I23, I18, I10, and I4 (19-m contour); I33, I30, I27, I22, I14, I16, I15, I12, I9, I6, I2, and I3 (28-m contour); I29, I21, I13, and I8 (38-m contour); I28, I20, I7, and I1 (55-m contour). Each sample was collected from one-half of a chain-rigged 0.1 m^2 double Van Veen grab; the other grab sample was used for macrofaunal community analysis (see Chapter 5). Sub-samples for various analyses were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987).

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Laboratory. Particle size analysis was

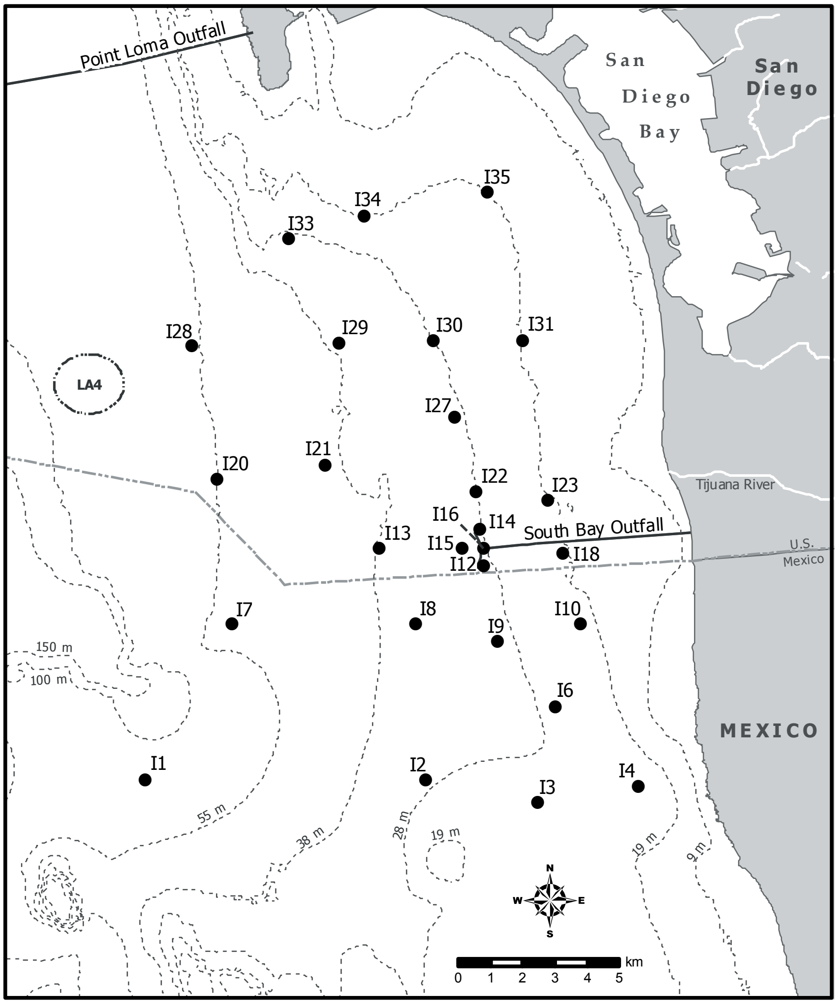

Figure 4.1
Benthic sediment station locations sampled for the South Bay Ocean Outfall Monitoring Program.

performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., -1 to 11 phi). Coarser sediments (e.g., very coarse sand, gravel, shell hash) were removed prior to analysis by screening the samples through a 2.0 mm mesh sieve. These data were expressed as the percent "Coarse" of the total sample sieved.

Data output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles from >0.0625 to 2.0 mm in size, silt as particles from 0.0625 to 0.0039 mm, and clay as particles <0.0039 mm (see **Table 4.1**). These data were standardized and incorporated with a sieved coarse fraction containing particles >2.0 mm in diameter to obtain a distribution of coarse, sand, silt, and clay totaling 100%. The coarse fraction was included with the ≥2.0 mm fraction in the calculation of various particle size parameters, which were determined using a normal probability scale (see Folk 1968). The parameters included mean and median particle size in millimeters, phi size, standard deviation of phi (sorting coefficient), skewness, kurtosis and percent sediment type (i.e., coarse, sand, silt, clay).

Chemical parameters analyzed for each sediment sample included total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl compounds (PCBs) (see **Appendix C.1**). These data were generally limited to values above the method detection limit (MDL). However, concentrations below the MDL were reported as estimated values if their presence could be verified by mass-spectrometry (i.e., spectral peaks confirmed), or

Table 4.1

A subset of the Wentworth scale representative of the sediments encountered in the SBOO region. Particle size is presented in phi, microns, and millimeters along with the conversion algorithms. The sorting coefficients (standard deviation in phi units) are based on categories described by Folk (1968).

Wentworth scale				Sorting coefficient	
Phi size	Microns	Millimeters	Description	Standard deviation	Sorting
-2	4000	4	Pebble	Under 0.35 phi	very well sorted
-1	2000	2	Granule	0.35–0.50 phi	well sorted
0	1000	1	Very coarse sand	0.50–0.71 phi	moderately well sorted
1	500	0.5	Coarse sand	0.71–1.00 phi	moderately sorted
2	250	0.25	Medium sand	1.00–2.00 phi	poorly sorted
3	125	0.125	Fine sand	2.00–4.00 phi	very poorly sorted
4	62.5	0.0625	Very fine sand	Over 4.00 phi	extremely poorly sorted
5	31	0.0310	Coarse silt		
6	15.6	0.0156	Medium silt		
7	7.8	0.0078	Fine Silt		
8	3.9	0.0039	Very fine silt		
9	2.0	0.0020	Clay		
10	0.98	0.00098	Clay		
11	0.49	0.00049	Clay		

Conversions for diameter in phi to millimeters: $D(mm) = 2^{-phi}$

Conversions for diameter in millimeters to phi: $D(phi) = -3.3219\log_{10}D(mm)$

as not detected (i.e., null) if not confirmed. Zeroes were substituted for all null values when calculating mean values. Annual mean concentrations are reported as the mean±standard deviation of station-quarter values.

Concentrations of the sediment constituents that were detected in 2006 were compared to average results from previous years, including the pre-discharge period (1995–1998). In addition, values for trace metals, TOC, TN, and pesticides (i.e., DDT) were compared to median values for the Southern California Bight (SCB). These medians were based on the cumulative distribution function (CDF) calculated for each parameter using data from the SCB region-wide survey in 1994 (see Schiff and Gossett 1998). They are presented as the 50% CDF in the tables included herein. Levels of contamination were further evaluated by comparing the results of this study to the Effects Range Low (ERL) sediment quality guideline of Long et al. (1995). The National Status and Trends Program of the National Oceanic and Atmospheric Administration originally calculated the ERL to provide a means for interpreting monitoring data. The ERL represents chemical concentrations below which adverse biological effects were rarely observed.

RESULTS AND DISCUSSION

Particle Size Distribution

Sediment composition at sites surrounding the SBOO ranged from very fine to coarse sands (0.064–0.609 mm) in 2006 with an area-wide mean of 0.258 mm (**Table 4.2**). Generally, stations located farther offshore and southward of the SBOO had coarser sediments than those located inshore and to the north of the outfall (**Figure 4.2**). This pattern is primarily due to deposits of coarse red relict sands found at several of these stations (e.g., I6, I7, I13, I20, I21; see **Appendix C.2**). Stations located along the shallower 19 and 28-m contours and towards the mouth of San Diego Bay typically had finer sediments (diameter <0.125 mm), with samples collected at stations I23 and I34 being notable exceptions (see below). The higher silt content at

Table 4.2

Annual means (n=2) for particle size parameters and organic loading indicators at SBOO stations during 2006. CDF=cumulative distribution functions (see text); na=not available. MDL=method detection limit. Area Mean=mean for all stations. Pre-discharge period = 1995–1998. Bolded values exceed the median CDF.

	Particle Size						Organic Indicators		
Station	Mean (mm)	Mean (phi)	SD (phi)	Coarse (%)	Sand (%)	Fines (%)	Sulfides ppm	TN WT%	TOC WT%
CDF						38.5	na	0.051	0.748
MDL							0.14	0.005	0.010
19 m stations									
I35	0.064	4.0	1.45	0.0	59.5	**40.5**	32.15	0.037	0.415
I34	0.511	1.1	1.10	19.8	79.3	0.9	0.15	0.000	**0.800**
I31	0.124	3.0	0.60	0.2	92.4	7.5	1.17	0.021	0.210
I23	0.457	1.8	1.10	19.0	73.4	7.7	1.44	0.015	**3.487**
I18	0.111	3.2	0.65	0.2	90.0	9.9	2.12	0.014	0.123
I10	0.118	3.1	0.65	0.2	91.5	8.4	1.09	0.017	0.143
I4	0.135	2.9	0.85	0.2	92.2	7.7	3.01	0.019	0.282
28 m stations									
I33	0.124	3.1	1.05	0.4	86.6	13.0	14.06	0.023	0.544
I30	0.102	3.3	1.00	0.4	83.8	15.8	6.48	0.020	0.190
I27	0.109	3.2	0.75	0.2	88.0	11.9	1.15	0.019	0.174
I22	0.156	2.8	1.05	0.5	89.1	10.5	7.28	0.019	0.162
I16	0.160	2.7	1.00	0.2	91.6	8.3	1.37	0.017	0.138
I15	0.323	1.7	1.00	3.7	92.5	3.8	0.24	0.012	0.084
I14	0.111	3.2	1.00	0.2	85.7	14.2	10.89	0.023	0.225
I12	0.262	2.2	0.80	2.4	93.1	4.6	0.39	0.009	0.105
I9	0.093	3.5	1.00	0.2	80.5	19.4	9.19	0.028	0.280
I6	0.519	1.0	0.75	8.6	91.3	0.2	0.09	0.013	0.152
I3	0.400	1.4	0.80	5.6	94.5	0.0	0.78	0.006	0.052
I2	0.343	1.5	0.80	4.3	95.7	0.0	0.30	0.006	0.063
38 m stations									
I29	0.080	3.7	1.15	0.1	70.0	30.0	5.08	0.036	0.500
I21	0.609	0.7	0.60	10.8	89.2	0.0	0.08	0.005	0.068
I13	0.528	1.0	0.75	8.3	91.1	0.7	0.24	0.008	0.148
I8	0.478	1.1	0.80	7.4	91.3	1.3	0.24	0.008	0.080
55 m stations									
I28	0.084	3.7	2.05	3.9	61.5	34.7	11.00	0.041	**0.788**
I20	0.302	1.9	1.80	7.4	78.3	14.4	0.19	0.013	0.123
I7	0.550	0.9	0.80	10.4	88.5	1.1	0.19	0.011	0.099
I1	0.131	3.0	0.90	0.0	91.2	8.8	0.74	0.022	0.250
Area Mean	0.258	2.4	0.97	4.2	85.6	10.2	4.11	0.017	0.359
Pre-discharge	0.213	2.3	0.80	1.4	87.7	10.2	4.59	0.019	0.143

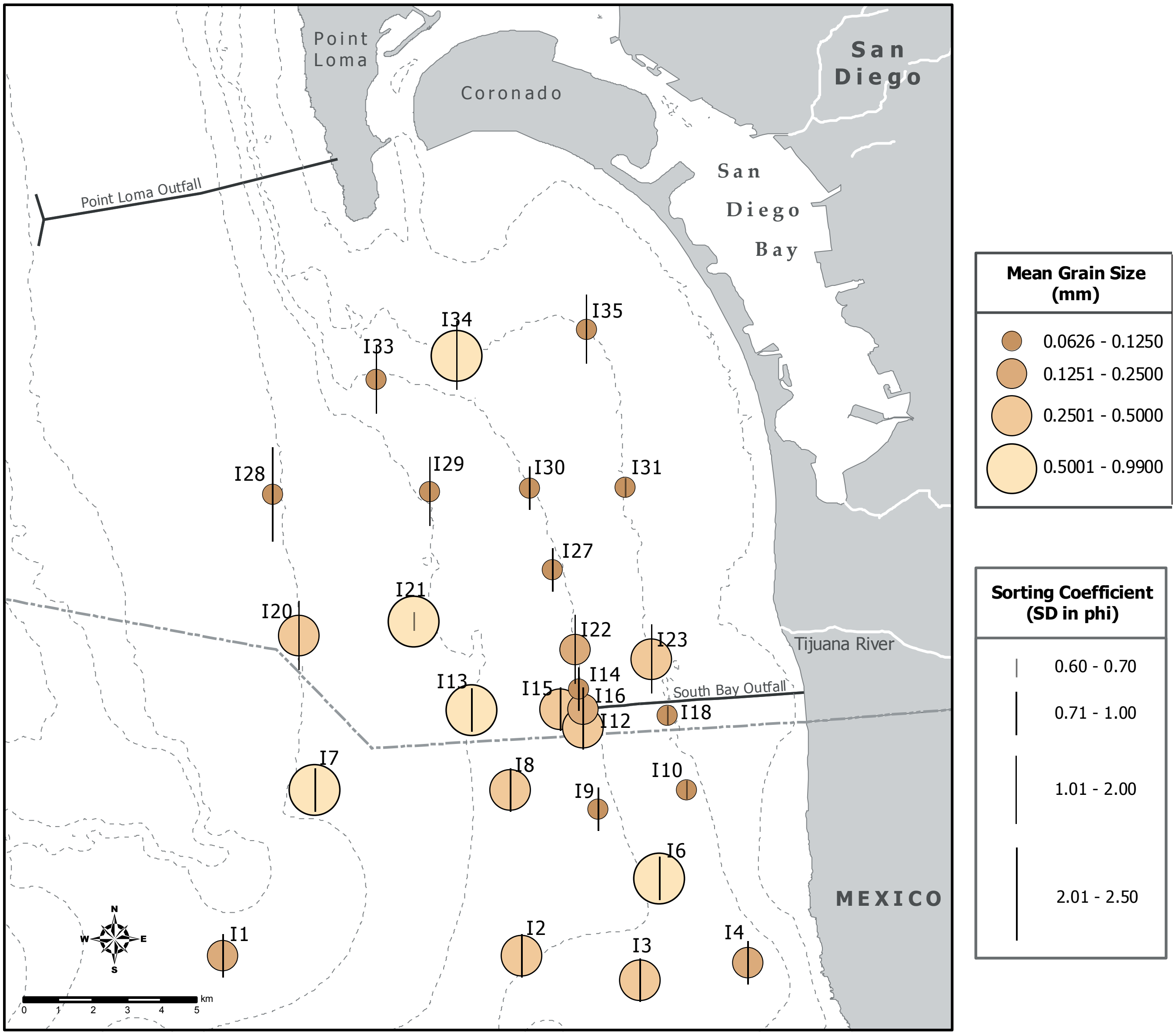

Figure 4.2

Mean particle size distribution for SBOO sediment chemistry stations sampled during January and July 2006. Mean particle size is based on diameter in millimeters, with sorting coefficient (standard deviation) in phi units.

most shallower stations is probably due to sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay (see City of San Diego 1988, 2003a).

Several stations experienced relatively large differences in sediment composition between the January and July surveys. The greatest difference occurred at stations I23 and I34 where mean particle size differed by approximately 0.7 and 0.4 mm, respectively (Appendix C.2). Station I34 is located just south of the channel that enters San Diego Bay, and maintenance dredging of the harbor entrance channel may occasionally affect sediments in the area. The last documented dredging in the area occurred in September 2004 (www.portofsandiego.org/projects/harbordredging/). Station I23 is located in shallow water offshore of the Tijuana River, where increased runoff from storms may impact sediment deposition or removal. Substantial (~30%) differences in the amount of coarse materials between surveys occurred at both stations (I23 and I34). Red relict sands, cobble, and coarse sands were collected at station I34 in January, but not in July. In contrast, large amounts of coarse sands were collected at station I23 in July

Table 4.3

Summary of changes in mean particle size and organic indicators for 1995–2006. Particle size is in phi and millimeters (mm). SD=the sorting coefficient, standard deviation (phi). Coarse is the percent material greater than -1 phi or 2 mm. TN and TOC=Total nitrogen and total organic carbon expressed as percent weight (wt %).

Year	Phi	mm	SD	% Fines	% Coarse	Sulfides	TN	TOC
1995	2.6	0.212	0.8	12.0	2.6	2.88	0.019	0.148
1996	2.6	0.206	0.9	11.2	0.8	3.23	0.022	0.149
1997	2.5	0.219	0.7	9.5	0.7	6.32	0.019	0.147
1998	2.5	0.214	0.7	9.0	2.1	5.11	0.017	0.132
1999	2.5	0.237	0.7	8.8	0.9	2.39	0.017	0.129
2000	2.5	0.208	0.8	8.8	1.0	4.32	0.021	0.130
2001	2.3	0.254	0.8	8.4	1.5	0.91	0.015	0.149
2002	2.4	0.259	0.8	9.8	2.3	0.78	0.016	0.139
2003	2.3	0.243	0.9	8.8	3.3	2.61	0.015	0.119
2004	2.3	0.263	1.1	9.1	4.5	2.93	0.018	0.135
2005	2.2	0.265	1.1	10.1	4.8	1.43	0.023	0.186
2006	2.4	0.258	1.0	10.2	4.2	4.11	0.017	0.234

that were not present in January. Other sites that experienced differences of at least 0.2 mm in mean grain size between surveys include station I15 near the SBOO discharge site and station I20 located further offshore along the 55-m contour.

The sorting coefficient reflects the range of grain sizes comprising sediments and is calculated as the standard deviation of the grain size in phi (see Table 4.1). Generally, areas composed of similarly sized particles are considered to have well-sorted sediments (SD ≤ 0.5 phi) suggestive of strong wave and current activity within an area (see Gray 1981). In contrast, particles of varied sizes have poorly sorted sediments (SD ≥1.0 phi) indicative of low wave and current activity. South Bay sediments were moderately to poorly sorted, suggesting either reduced wave and current velocity or some disturbance. Mean sorting coefficients in the area surrounding the SBOO ranged from 0.6–2.1 phi during the 2006 surveys, while individual sites averaged 0.9±0.4 phi (Table 4.2, Appendix C.2). Thirteen of the 27 stations had poorly sorted sediments (i.e., SD ≥1.0 phi), including 3 sites along the 19-m contour, 7 sites along the 28-m contour, 1 site along the 38-m contour, and 2 sites along the 55-m contour (see Figure 4.2). Station I35 near the mouth of San Diego Bay, and stations I20 and I28 along the 55-m contour had the highest mean sorting coefficients (>1.4 phi). The sorting coefficients for I28 and I35, along with station I29, have consistently been >1.0 (see City of San Diego 2006).

Overall mean particle size for the South Bay has increased over time (see **Table 4.3**). For example, mean particle size during the 1995–1998 period was <0.22 mm but has ranged from 0.243 to 0.265 mm since 2001. Particle size began to increase after 1998 when El Niño conditions produced powerful storms and heavy surf that eroded beaches along the San Diego coastline (City of San Diego 2003b, U.S. Army Corp of Engineers 2002). Drought conditions that persisted in San Diego from 1999 through early 2004 resulted in a reduction of runoff from rivers and bays that most likely caused a decrease in deposition of terrestrial fine particles onto the ocean shelf. In addition, record rainfall from October 2004 through February 2005 and associated heavy surf resulted in severe loss of beach sand from Imperial Beach as well as other beaches in San Diego County (Zúñiga 2005). Overall, the increase in particle size in the South Bay appears to be in part the result of accretion of coarser sediments lost from the Silver Strand littoral cell.

Indicators of Organic Loading

Mean concentrations of total organic carbon (TOC) in South Bay sediments in 2006 were higher than in previous surveys, whereas total nitrogen (TN) values declined slightly (see Table 4.3). For example, the area mean for TOC was 0.359% in 2006 compared to the previous high of 0.186% in 2005. This increase was due primarily to an abnormally high value (6.85%) measured at station I23 in July, along with 8 other stations (I4, I6, I14, I22, I23, I31, I33, I34, I35) that increased 25% or more in mean TOC concentration relative to 2005 (see City of San Diego 2006). All of these 9 stations are located in shallow waters or near San Diego Bay, the Tijuana River, and the SBOO. TOC concentrations at 3 sites (I23, I28, I34) were above the SCB median value. Although high compared to the surrounding deeper sites, these TOC values are similar to those located at similar depths from the July 2006 regional benthic survey (see Chapter 8). The higher TOC concentrations at these stations may represent a carry-over of persistent discharge from San Diego Bay and the Tijuana River during the winter of 2004–2005 that was laden with organic material, or die-off from the extensive 2004–2005 plankton bloom (see City of San Diego 2006). Although high concentrations of TOC typically correspond to higher concentrations of fine sediments (Emery 1960, Eganhouse and Venkatesan 1993), this was not necessarily true of samples collected in 2006. Of the above 9 sites, only 4 averaged percent fines above 10%, including just one of 3 sites with the highest average TOC concentration.

Sulfide concentrations averaged from 0.08 to about 32 ppm during the year. The area mean of 4.11 ppm in 2006 was higher than in 2005, and is due primarily to an exceptionally high value at station I35 (32.15 ppm). Unlike TOC or TN, higher sulfide concentrations tended to co-occur with sediments containing >10% fine particles. These stations included several sites north of the SBOO and (i.e., I14, I22, I27, I28, I29, I30, I33, I35) and only one southern site (I9). Overall, concentrations of organic loading indicators were similar to those of the random survey results and there was no pattern in relative to wastewater discharge.

Trace Metals

Aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, nickel, tin, and zinc were detected at 100% of the South Bay area stations in 2006 (**Table 4.4**). In contrast, antimony, mercury, silver, and thallium were detected less frequently, while selenium was not detected at all. Area means for most metals were lower in 2006 compared to prior years. For example, concentrations of 11 trace metals exceeded pre-discharge means in 2005 (see City of San Diego 2006), whereas only 5 metals did so in 2006. Moreover, 2006 mean concentrations of 8 metals (aluminum, arsenic, beryllium, chromium, iron, manganese, thallium, zinc) were equal to or lower than pre-discharge means.

Stations composed of coarse materials and red relict sands (I7, I13, I21) contained concentrations of arsenic above the median CDF. In addition, station I10, located along the 19-m contour south of the SBOO had concentrations of copper and zinc above the median CDF, while stations I29 and I35 had concentrations of antimony above the median. These high values were a result of significant increases between January and July of 4.2 to 99.2 ppt and 57.6 to 95.6 ppt for copper and zinc, respectively. Nearly all trace metal concentrations were below the ERL sediment quality thresholds for metals of concern (i.e., cadmium chromium, copper, lead, mercury, nickel, silver, zinc); exceptions were for arsenic at station I21 and copper at station I10.

Generally, there was no pattern in trace metal contamination related to proximity to the SBOO. Instead, metal concentrations were typically highest in sediments composed of high percentages of fine materials. Three stations (i.e., I28, I29, I35) containing 30% or more of fine materials contained nearly all of the highest or second highest concentrations of individual metals. Arsenic, which

Table 4.4

Annual mean concentrations of trace metals (parts per million) detected at each station during 2006. CDF=cumulative distribution function. MDL=method detection limit. ERL=effects range low threshold value. nd=not detected. Pre-discharge values (1995–1998). See Appendix A.1 for metal names represented by the periodic table symbols. Bolded values exceed the median CDF.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Ag	Tl	Sn	Zn
MDL	1.15	0.13	0.33	0.002	0.001	0.01	0.016	0.028	0.75	0.142	0.004	0.003	0.036	0.013	0.022	0.059	0.052
CDF	9400	0.2	4.80	na	0.26	0.29	34.0	12.0	16800	na	na	0.040	na	0.17	na	na	56.0
ERL	na	na	8.2	na	na	1.2	81	34	na	46.7	na	0.15	20.9	1.0	na	na	150
19 m stations																	
I35	9365	**0.3**	2.23	47.50	0.07	0.08	14.5	8.2	10550	5.31	101.0	0.019	5.7	0.12	0.14	1.0	26.2
I34	1405	0.1	1.58	6.85	0.01	0.01	4.1	2.9	3250	2.35	23.1	nd	0.7	nd	0.19	1.1	4.7
I31	3295	0.2	0.80	16.65	0.02	0.03	6.6	2.1	3140	1.64	35.5	nd	1.5	0.02	0.18	0.6	6.1
I23	3335	0.1	1.48	22.98	0.03	0.06	6.4	3.2	4115	2.02	40.8	nd	1.7	0.02	0.00	0.7	7.0
I18	4755	0.1	1.56	39.70	0.03	0.02	9.3	3.7	5695	2.04	55.7	nd	2.3	nd	0.12	0.6	10.6
I10	6140	0.2	1.36	50.25	0.03	0.02	8.9	**51.7**	6715	1.93	76.6	nd	2.8	0.03	nd	0.7	**74.1**
I4	3740	0.2	1.04	23.50	0.02	0.03	7.7	3.0	4045	2.22	41.8	nd	2.6	0.03	nd	0.6	8.8
28 m stations																	
I33	4800	0.1	1.89	23.65	0.03	0.04	8.4	4.1	6140	3.94	65.1	0.014	2.7	0.02	nd	0.9	14.2
I30	6560	0.2	1.85	32.45	0.04	0.06	11.0	4.2	6780	2.76	65.3	0.010	3.5	0.05	nd	0.7	16.2
I27	5690	0.1	1.28	28.95	0.03	0.03	9.3	3.5	5745	2.54	56.5	nd	2.9	0.06	0.12	0.7	13.0
I22	4190	0.1	1.53	21.00	0.03	0.05	8.3	2.5	4765	2.62	43.8	0.002	2.5	0.03	nd	0.8	10.3
I16	3305	0.1	1.38	24.35	0.03	0.06	7.1	3.1	4470	1.91	45.2	0.004	2.1	0.02	nd	0.9	10.1
I15	2310	0.1	2.13	10.45	0.03	0.03	8.1	1.7	4215	1.79	28.5	0.002	1.6	nd	nd	0.6	8.4
I14	6160	0.2	1.48	36.20	0.04	0.04	9.8	5.2	6575	2.95	67.4	0.002	3.3	0.09	0.15	0.6	16.3
I12	2975	0.1	1.57	17.56	0.02	0.05	7.0	3.3	4145	2.09	36.6	nd	1.7	0.07	0.07	0.6	9.2
I9	7490	0.2	1.08	45.35	0.04	0.03	12.1	5.9	7895	3.10	78.6	0.002	4.8	0.09	0.27	0.7	19.3
I6	1047	0.2	3.70	4.03	0.01	0.04	8.2	1.1	3740	1.45	11.8	nd	0.8	nd	nd	0.7	3.7
I3	589	nd	0.69	2.58	0.01	0.02	3.7	0.7	880	0.56	5.6	nd	0.5	0.05	nd	0.9	1.5
I2	1225	nd	0.46	2.21	0.01	0.01	6.0	1.7	1270	1.05	10.5	nd	0.9	0.06	nd	0.8	2.1
38 m stations																	
I29	8680	**0.3**	2.71	46.65	0.07	0.05	13.8	7.3	9885	4.41	90.0	0.008	5.8	0.06	0.22	1.0	22.7
I21	1030	0.1	**10.80**	2.10	0.02	0.09	10.7	2.5	8145	2.77	14.1	nd	0.8	nd	nd	0.9	5.8
I13	1079	0.2	**5.24**	2.66	0.01	0.05	10.2	2.5	5625	2.27	15.7	nd	1.2	nd	nd	0.6	5.2
I8	1395	nd	2.61	3.61	0.02	0.04	8.2	1.4	3790	1.25	15.5	nd	1.1	0.02	nd	0.6	6.0
55 m stations																	
I28	5315	0.2	2.89	27.45	0.06	0.06	10.5	6.5	7540	4.15	56.6	0.022	5.4	0.05	nd	1.1	17.1
I20	1605	0.1	2.40	4.00	0.03	0.03	5.8	1.5	4405	1.75	16.9	0.002	1.4	nd	nd	0.7	6.6
I7	1053	0.2	**6.44**	2.12	0.01	0.06	9.3	1.7	6685	2.16	14.7	nd	0.8	nd	nd	0.7	5.2
I1	3080	0.2	0.94	11.16	0.03	0.06	7.4	3.7	3985	2.31	35.9	0.007	2.2	nd	nd	0.7	7.6
Detection rate	100	89	100	100	100	100	100	100	100	100	100	44	100	67	33	100	100
Area mean	3763	0.1	2.34	20.59	0.03	0.04	8.6	5.1	5340	2.42	42.5	0.003	2.3	0.03	0.05	0.8	12.5
Pre-discharge	5164	0.08	2.47	NA	0.13	nd	10.2	2.6	6568	0.09	55.4	0.002	1.9	nd	0.20	nd	12.5

Table 4.5

Annual mean concentrations of pesticides and PAHs detected at each station during 2006. Beta endosulphan=(b)E; hexachlorobenzene=HCB; total DDT=tDDT; nd=not detected.

STATION	DEPTH (m)	(b)E (ppb)	HCB (ppb)	tDDT (ppb)	tPAH (ppt)	tPAH No.
19 m stations						
I35	19	nd	nd	nd	151.0	9
I34	19	nd	nd	nd	106.7	11
I31	19	nd	nd	nd	129.0	7
I23	21	nd	nd	nd	110.2	7
I18	19	nd	nd	nd	119.5	6
I10	19	nd	300	nd	93.0	5
I4	18	nd	305	nd	133.2	7
28 m stations						
I33	30	410	nd	nd	101.7	6
I30	28	nd	nd	nd	119.4	5
I27	28	nd	nd	nd	86.9	5
I22	28	nd	nd	nd	137.5	9
I16	28	nd	375	nd	110.7	5
I15	31	nd	nd	nd	123.4	7
I14	28	nd	nd	nd	123.4	6
I12	28	nd	375	nd	109.3	11
I9	29	nd	305	nd	146.4	5
I6	26	nd	nd	nd	111.0	6
I3	27	nd	nd	nd	135.0	8
I2	32	nd	nd	nd	119.9	6
38 m stations						
I29	38	nd	nd	920	133.9	6
I21	41	nd	nd	nd	102.5	8
I13	38	nd	nd	nd	96.2	6
I8	36	nd	nd	nd	91.6	5
55 m stations						
I28	55	nd	nd	845	79.8	10
I20	55	nd	nd	nd	115.0	7
I7	52	nd	nd	nd	102.9	7
I1	60	nd	nd	nd	121.9	9

was the most prevalent trace metal at stations with coarse materials, was the single exception to this pattern.

Pesticides

Low levels of 3 types of chlorinated pesticides were detected in sediment samples collected from just a few stations in 2006 (**Table 4.5**). Beta endosulfan was collected at station I33 at a concentration of 820 ppt in July; hexachlorobenzene (HCB) was collected at concentrations ranging from 600–750 ppt at 4 stations (I9, I10, I12, I16) in January and one station in July (I10); and p,p-DDE, a DDT derivative, was found at stations I28 and I29 during January and July with mean concentrations of 845 and 920 ppt, respectively. Two of the 4 January samples containing HCB were collected near the SBOO outfall at stations I12 and I16, while 2 others were collected at more southern stations (I9, I10). HCB has a variety of sources, including as a by-product of production of various regulated organic compounds, in the manufacture of fireworks, or the incineration of municipal wastes. Currently there are no commercial uses of HCB in the United States (DHHS—ASTDR 2002). Concentrations of DDT were lower than the median CDF value of 1200 ppt for this pesticide, and significantly lower than the ERL of 2200 ppt. Station I28 has had elevated pesticide levels in the past, which are most likely related to contamination from dredge disposal materials (see City of San Diego 2001, 2003a).

PCBs and PAHs

PCBs were not detected in sediments from any station during 2006, while low levels of 17 PAH compounds were detected at all stations (Table 4.5). The PAH values were near or below MDL levels and should therefore be viewed with caution. The detection of low levels of PAHs at these stations appears to reflect a change in methodology where values below MDLs can be reliably estimated with qualitative identification via a mass spectrophotometer (see City of San Diego 2004). All of the values were well below the ERL of 4022 ppt for total PAH. There did not appear to be a relationship between PAH concentrations and proximity to the outfall.

SUMMARY AND CONCLUSIONS

Sediments at the South Bay sampling sites consisted mainly of very fine to coarse sands in 2006. Spatial patterns in sediment composition within the region may be partially attributed to the multiple geological origins of red relict sands, shell hash, coarse sands, and other detrital sediments (Emery 1960). Stations located offshore and southward of the SBOO consisted of very coarse sediments. In contrast, stations located in shallower water and north of the outfall towards the mouth of San Diego Bay generally had finer sediments. Sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay probably contributes to the higher content of silt at these stations (see City of San Diego 1988). Overall, mean particle size has increased over time, from pre-discharge means between 0.206–0.237 mm to post-discharge means between 0.243–0.265 mm. This increased particle size appears to be unrelated to wastewater discharge and may, in part, be the result of accretion of coarser sediments lost from the Silver Strand littoral cell or from storm-related deposition/erosion.

Although there was an overall increase in concentrations of sulfides and total organic carbon in South Bay sediments for 2006 compared to prior years, individual values generally remained low compared to the southern California continental shelf (see Noblet et al. 2003, Schiff and Gossett 1998). A relatively large increase in TOC in 2006 was related to increased concentrations at several shallow water stations located near San Diego Bay and offshore of the Tijuana River, particularly the July sediments at station I23. The TOC content at this station was 6.85%, a value typically associated with severely impacted areas (see Zeng et al 1995). Some of these increases may represent a carry-over of the persistent discharge from San Diego Bay and the Tijuana River during the winter of 2004–2005 which was laden with organic material or remnants of a lasting plankton bloom (see City of San Diego 2006).

Concentrations of most trace metals decreased in 2006 relative to previous surveys. Generally, trace metal concentrations in the SBOO sediments were near or below pre-discharge levels, and low compared to median values for southern California. Only a few stations contained trace metals concentrations above the SCB median value: stations I7, I13, I21 (arsenic); station I10 (copper and zinc); stations I29 and I35 (antimony). In addition, arsenic and copper levels were above the ERL sediment quality thresholds at stations I21 and I10, respectively. The elevated arsenic concentrations occurred where coarse materials including red relict sands were predominant. Such sediments typically contain high concentrations of arsenic. Higher concentrations of organic compounds and most trace metals were generally associated with finer sediments. This pattern is consistent with that found in other studies, in which the accumulation of fine particles has been shown to greatly influence the organic and metal content of sediments (e.g., Eganhouse and Venkatesan 1993).

Other sediment contaminants were rarely detected during 2006. For example, PCBs were not detected at all. Low levels of chlorinated pesticides were detected at only 7 stations, while PAHs were found at all stations but at concentrations near or below their respective method detection limits. Overall, there was no pattern in sediment contaminant concentrations relative to the SBOO discharge.

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